

# **What Is a Control Chart?**

A statistical tool used to distinguish between process variation resulting from common causes and variation resulting from special causes.

# **Why Use Control Charts?**

- Monitor process variation over time
- Differentiate between special cause and common cause variation
- Assess effectiveness of changes
- Communicate process performance

# **What Are the Control Chart Types?**

## **Chart types studied in this module:**

*X-Bar and R Chart*

*Individual X and Moving Range Chart*

- *For Variables Data*
- *For Attribute Data*

## **Other Control Chart types:**

X-Bar and S Chart

u Chart

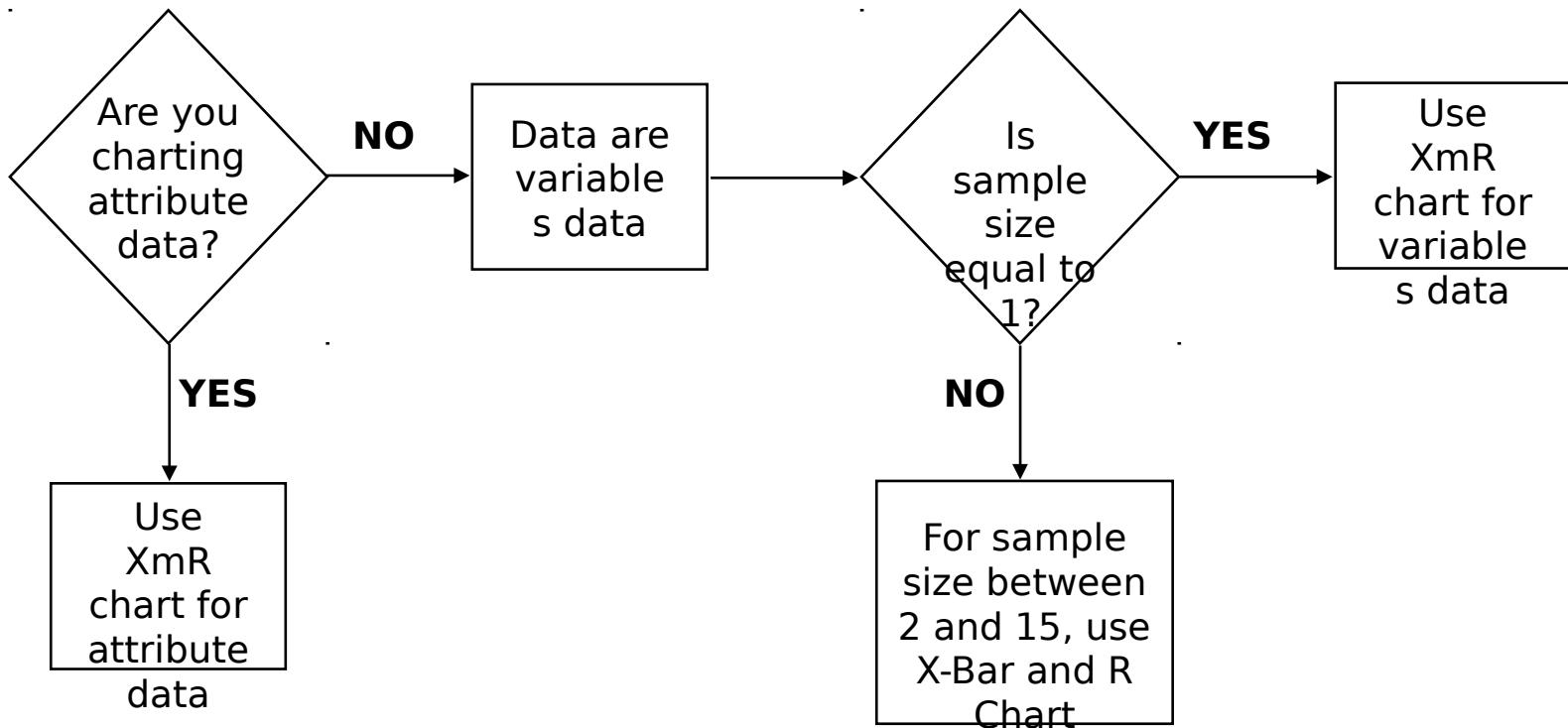
Median X and R Chart

p Chart

c Chart

np Chart

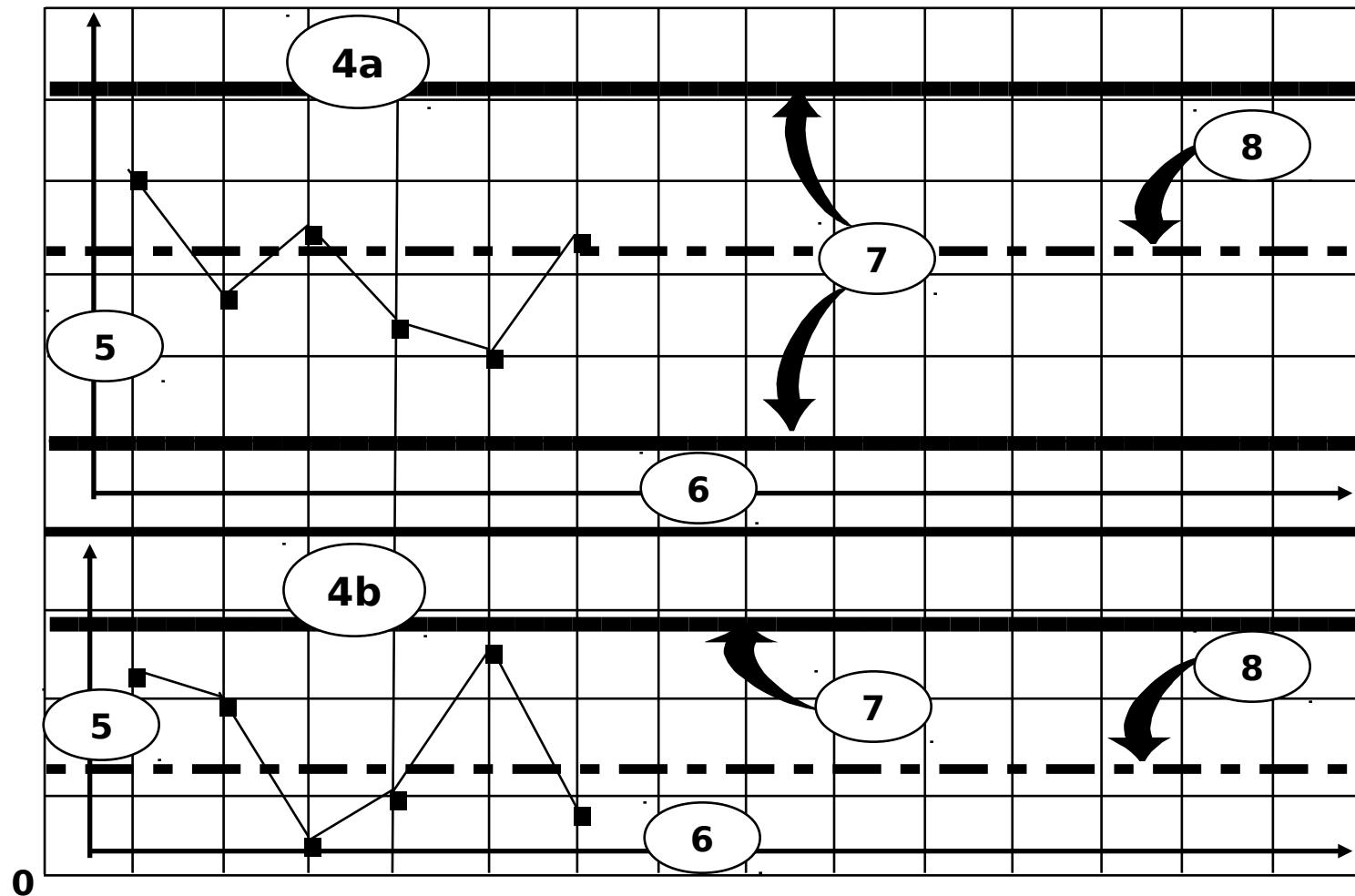
# Control Chart Decision Tree



# Elements of a Control Chart

Title: <span style="border: 1px solid black; border-radius: 50%; padding: 2px 10px;">1</span>		Legend: <span style="border: 1px solid black; border-radius: 50%; padding: 2px 10px;">2</span>													
Date															
M E A S U R E M E N T S	1														
	2														
	3														
	4														
	5														
	6														
	Average														
Range															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14

# Elements of a Control Chart



# Constructing an X-Bar & R Chart

## Step 2 - Collect and enter data by subgroup

Title: _____		Legend: _____																
Date	1 Feb	2 Feb	3 Feb	4 Feb	5 Feb	6 Feb	7 Feb	8 Feb	9 Feb									
M E A S U R E M E N T S	1	15.3	14.4	15.3	15.0	15.3	14.9	15.6	14.0	14.0								
	2	14.9	15.5	15.1	14.8	16.4	15.3	16.4	15.8	15.2								
	3	15.0	14.8	15.3	16.0	17.2	14.9	15.3	16.4	13.6								
	4	15.2	15.6	18.5	15.6	15.5	16.5	15.3	16.4	15.0								
	5	16.4	14.9	14.9	15.4	15.5	15.1	15.0	15.3	15.0								
Average																		
Range																		
		1	2	3	4	5	6	7	8	9								
A V E R A G E																		

Enter data by  
subgroup in time  
sequence

# Constructing an X-Bar & R Chart

## Step 3 - Calculate and enter subgroup averages

Title: \_\_\_\_\_

averages

Legend: \_\_\_\_\_

Date	1 Feb	2 Feb	3 Feb	4 Feb	5 Feb	6 Feb	7 Feb	8 Feb	9 Feb									
M E A S U R E M E N T S	1	15.3	14.4	15.3	15.0	15.3	14.9	15.6	14.0	14.0								
	2	14.9	15.5	15.1	14.8	16.4	15.3	16.4	15.8	15.2								
	3	15.0	14.8	15.3	16.0	17.2	14.9	15.3	16.4	13.6								
	4	15.2	15.6	18.5	15.6	15.5	16.5	15.3	16.4	15.0								
	5	16.4	14.9	14.9	15.4	15.5	15.1	15.0	15.3	15.0								
Average	15.36	15.04	15.82	15.36	15.98	15.34	15.52	15.58	14.56									
Range																		
	1	2	3	4	5	6	7	8	9									
A V E R A G E																		

Enter the average  
for each subgroup

# Constructing an X-Bar & R Chart

## Step 4 - Calculate and enter subgroup

Title: \_\_\_\_\_

ranges

Legend: \_\_\_\_\_

Date	1 Feb	2 Feb	3 Feb	4 Feb	5 Feb	6 Feb	7 Feb	8 Feb	9 Feb									
M E A S U R E M E N T S	1	15.3	14.4	15.3	15.0	15.3	14.9	15.6	14.0	14.0								
	2	14.9	15.5	15.1	14.8	16.4	15.3	16.4	15.8	15.2								
	3	15.0	14.8	15.3	16.0	17.2	14.9	15.3	16.4	13.6								
	4	15.2	15.6	18.5	15.6	15.5	16.5	15.3	16.4	15.0								
	5	16.4	14.9	14.9	15.4	15.5	15.1	15.0	15.3	15.0								
Average	15.36	15.04	15.82	15.36	15.98	15.34	15.52	15.58	14.56									
Range	1.5	1.2	3.6	1.2	1.9	1.6	1.4	2.4	1.6									
	1	2	3	4	5	6	7	8	9									
A V E R A G E																		

Enter the range for each subgroup

# **Constructing an X-Bar & R Chart**

**Step 5** - Calculate grand mean

**Step 6** - Calculate average of subgroup ranges

**Step 7** - Calculate UCL and LCL for subgroup averages

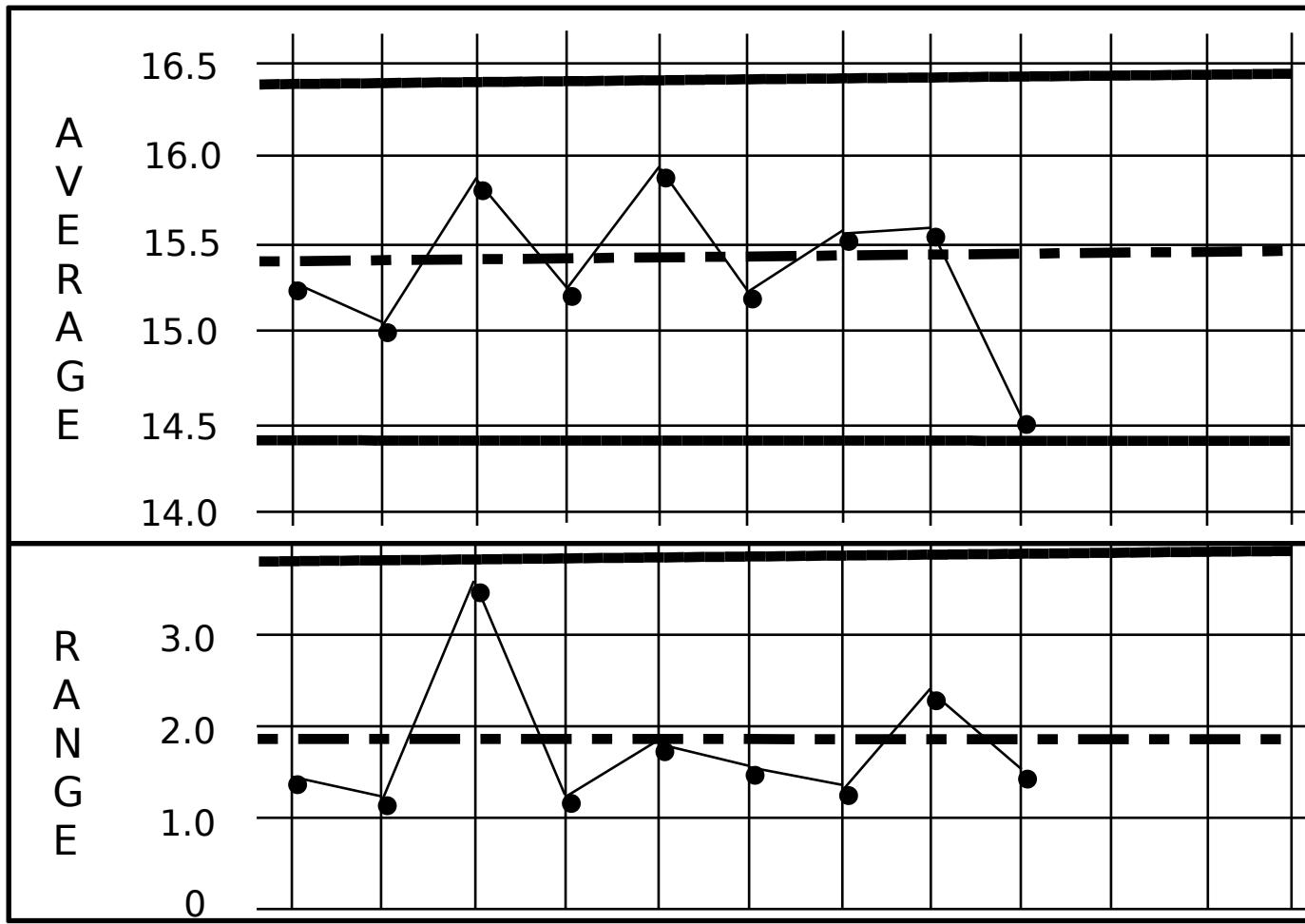
**Step 8** - Calculate UCL for ranges

**Step 9** - Select scales and plot

**Step 10** - Document the chart

# Constructing an X-Bar & R Chart

## Step 9 - Select scales and plot



# Constructing an XmR Chart

## Step 2 - Collect and enter individual

Title: \_\_\_\_\_

measures

Entered:

Date	1 Apr	2 Apr	3 Apr	4 Apr	5 Apr	6 Apr	7 Apr	8 Apr	9 Apr	10 Apr		

Individual	19	22	16	18	19	23	18	15	19	18		
X Moving R												
	1	2	3	4	5	6	7	8	9	10		

I N D I V I D U A L X												

Enter individual  
measurements in  
time sequence

# **Constructing an XmR Chart**

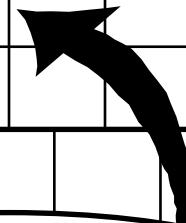
## **Step 3 - Calculate and enter moving ranges**

Title: \_\_\_\_\_ Legend: \_\_\_\_\_

Date 1 Apr 2 Apr 3 Apr 4 Apr 5 Apr 6 Apr 7 Apr 8 Apr 9 Apr 10 Apr

A solid blue rectangular background with a thin black border on the left side.

Individual	19	22	16	18	19	23	18	15	19	18		
Moving R	X	3	6	2	1	4	5	3	4	1		
	1	2	3	4	5	6	7	8	9	10		



# Enter the moving ranges

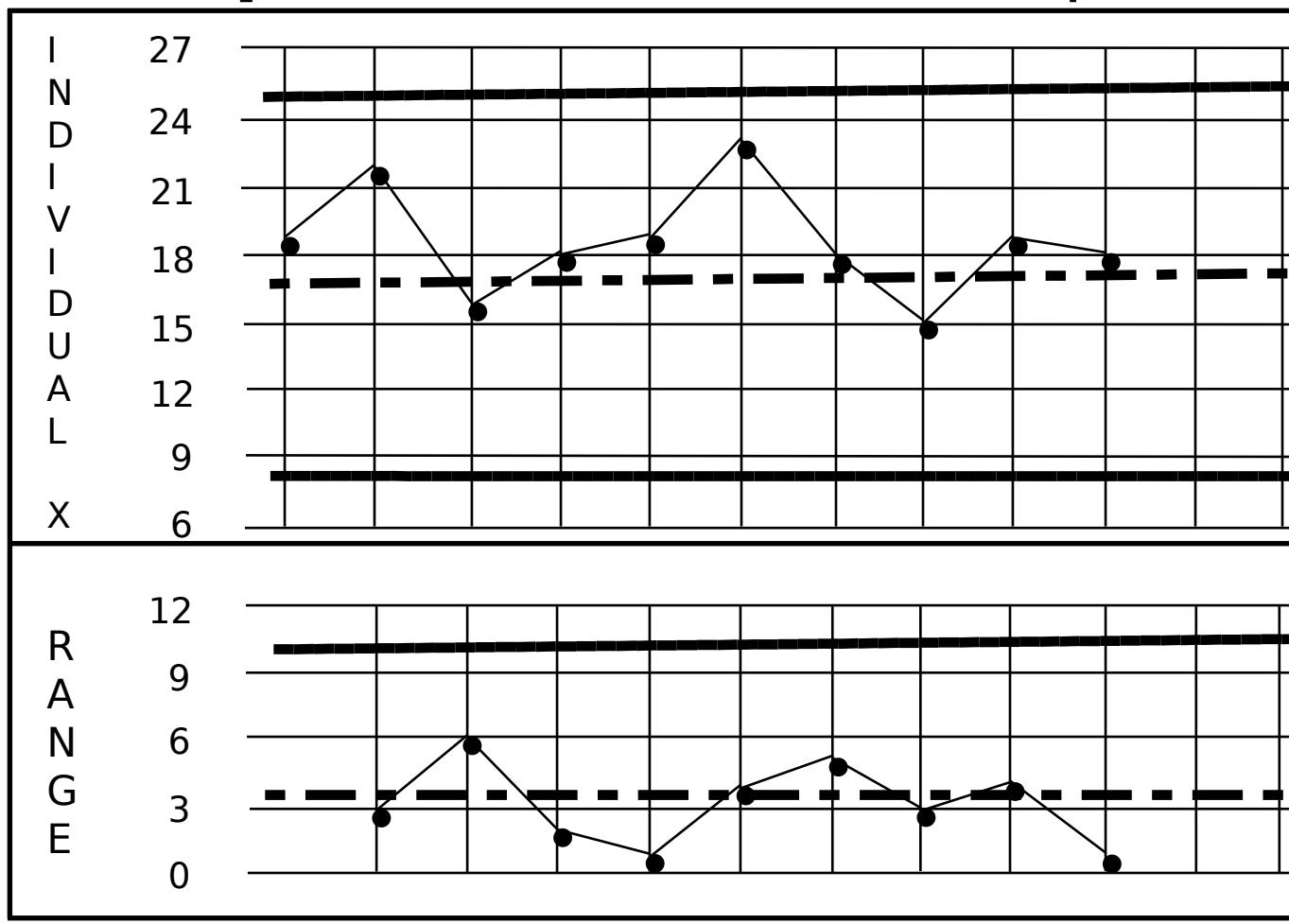
INDIVIDUAL X

# **Constructing an XmR Chart**

- Step 4** - Calculate average of data points
- Step 5** - Calculate average of moving ranges
- Step 6** - Calculate UCL and LCL for individual  
 $X$
- Step 7** - Calculate UCL for ranges
- Step 8** - Select scales and plot
- Step 9** - Document the chart

# Constructing an XmR Chart

## Step 8 - Select scales and plot

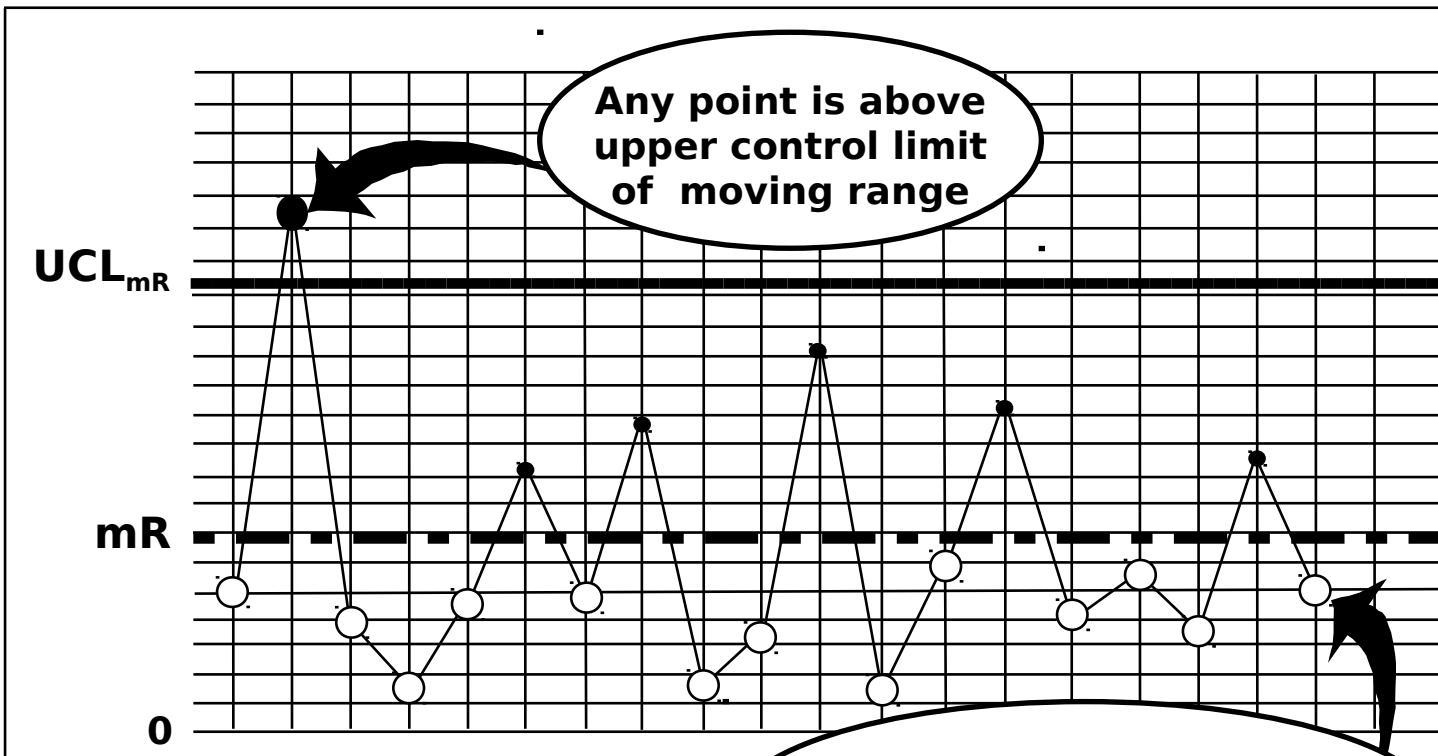


# Constructing an XmR Chart

- Step 10** - Check for *inflated* control limits
- Step 11** - If inflated, calculate 3.144 times median mR
- Step 12a** - Do not recompute if 3.144 times median mR is greater than 2.66 times average of moving ranges
- Step 12b** - Otherwise, recompute all control limits and centerlines

# Constructing an XmR Chart

## Step 10 - Check for inflated control limits



# **Step 12b - Constructing an XmR Chart**

## **Upper Plot**

$UCL_x = \bar{X} + (3.144) (\text{Median Moving Range})$

$LCL_x = \bar{X} - (3.144) (\text{Median Moving Range})$

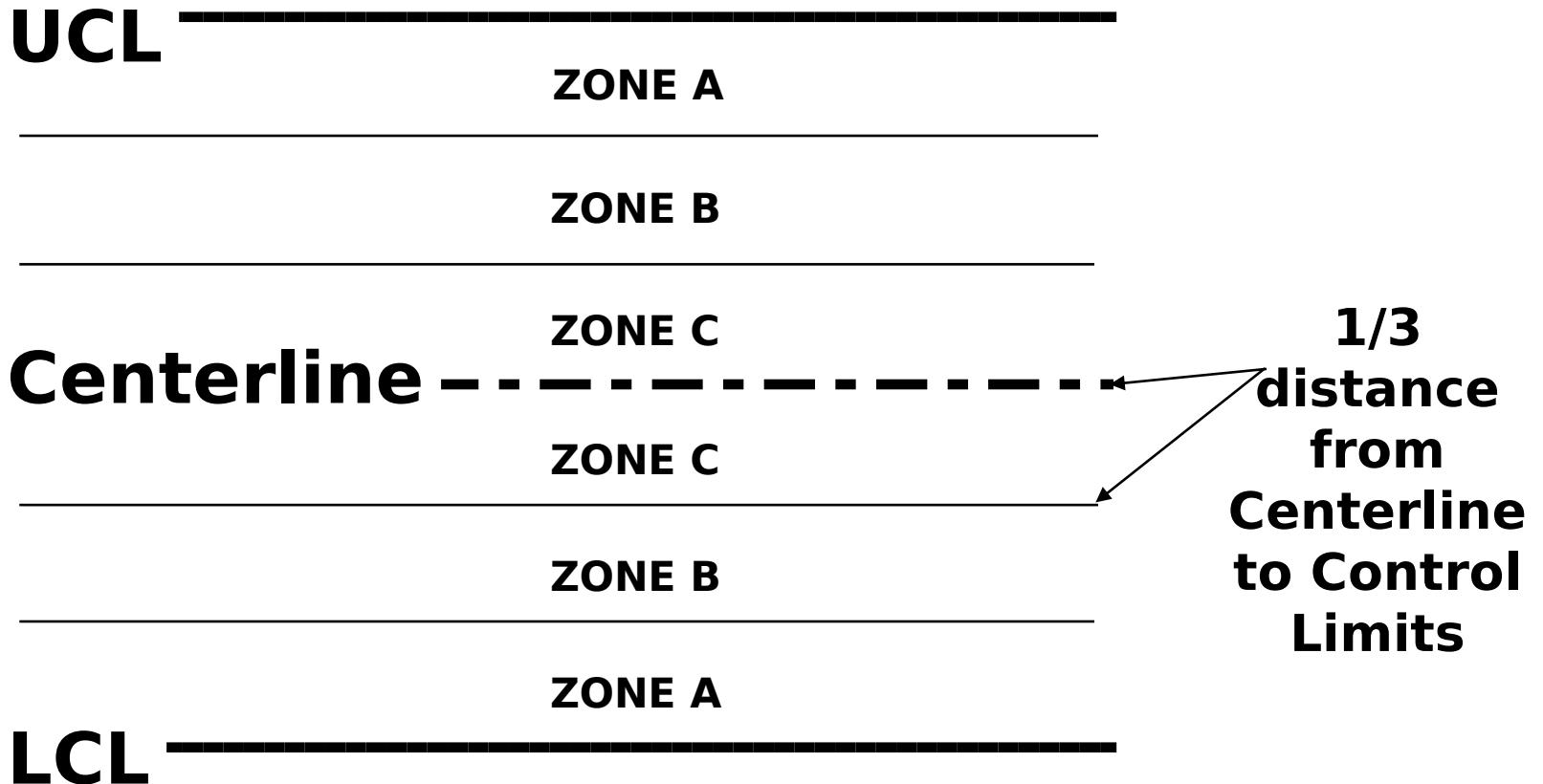
Centerline<sub>x</sub> =  $\bar{X}$

## **Lower Plot**

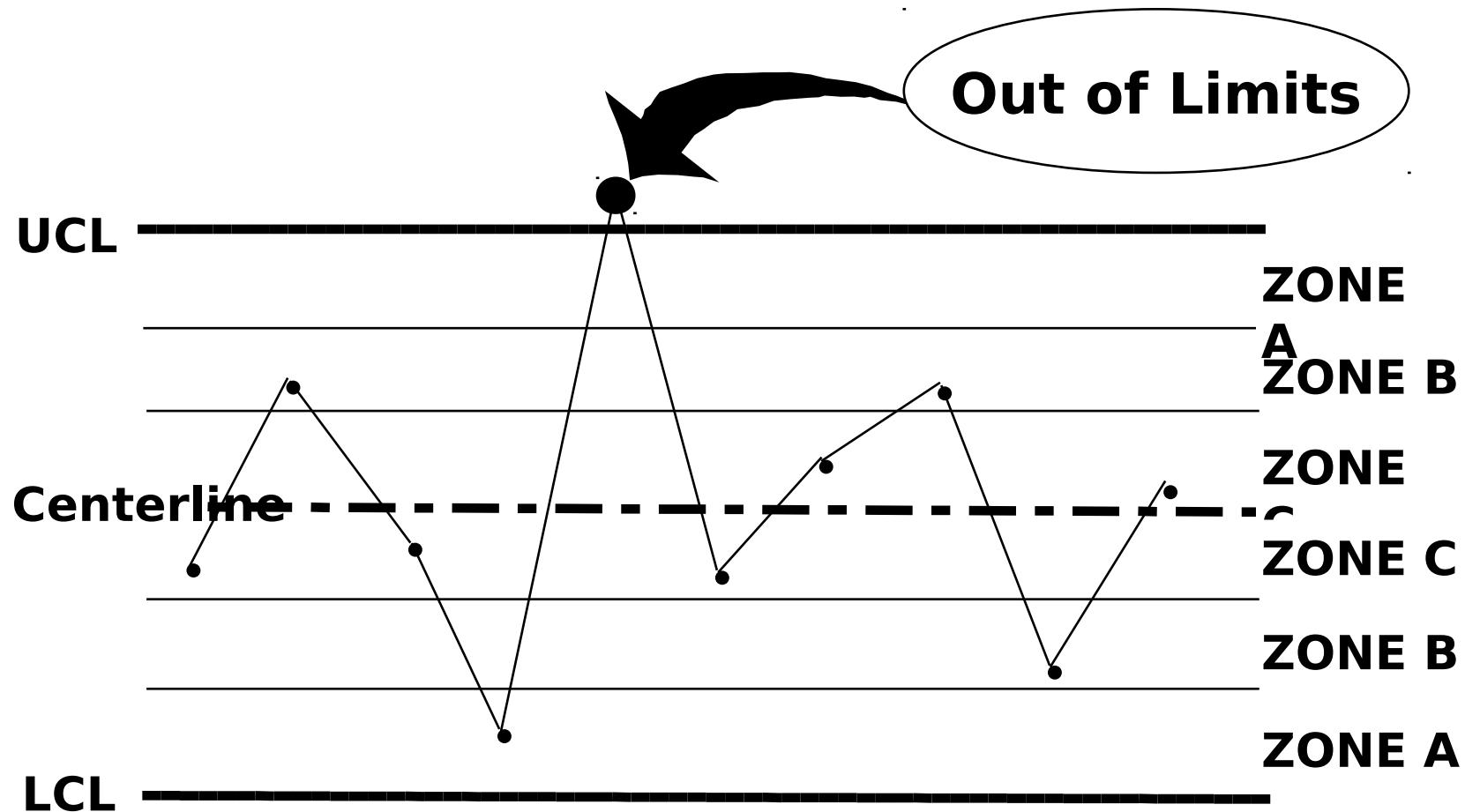
$UCL_{mR} = (3.865) (\text{Median Moving Range})$

$LCL_{mR} = \text{None}$

# Control Chart Zones



# Rule 1 - Interpreting X-Bar & R Charts



# Rule 2 - Interpreting X-Bar & R Charts

UCL

Centerline

LCL

ZONE  
A

ZONE  
B

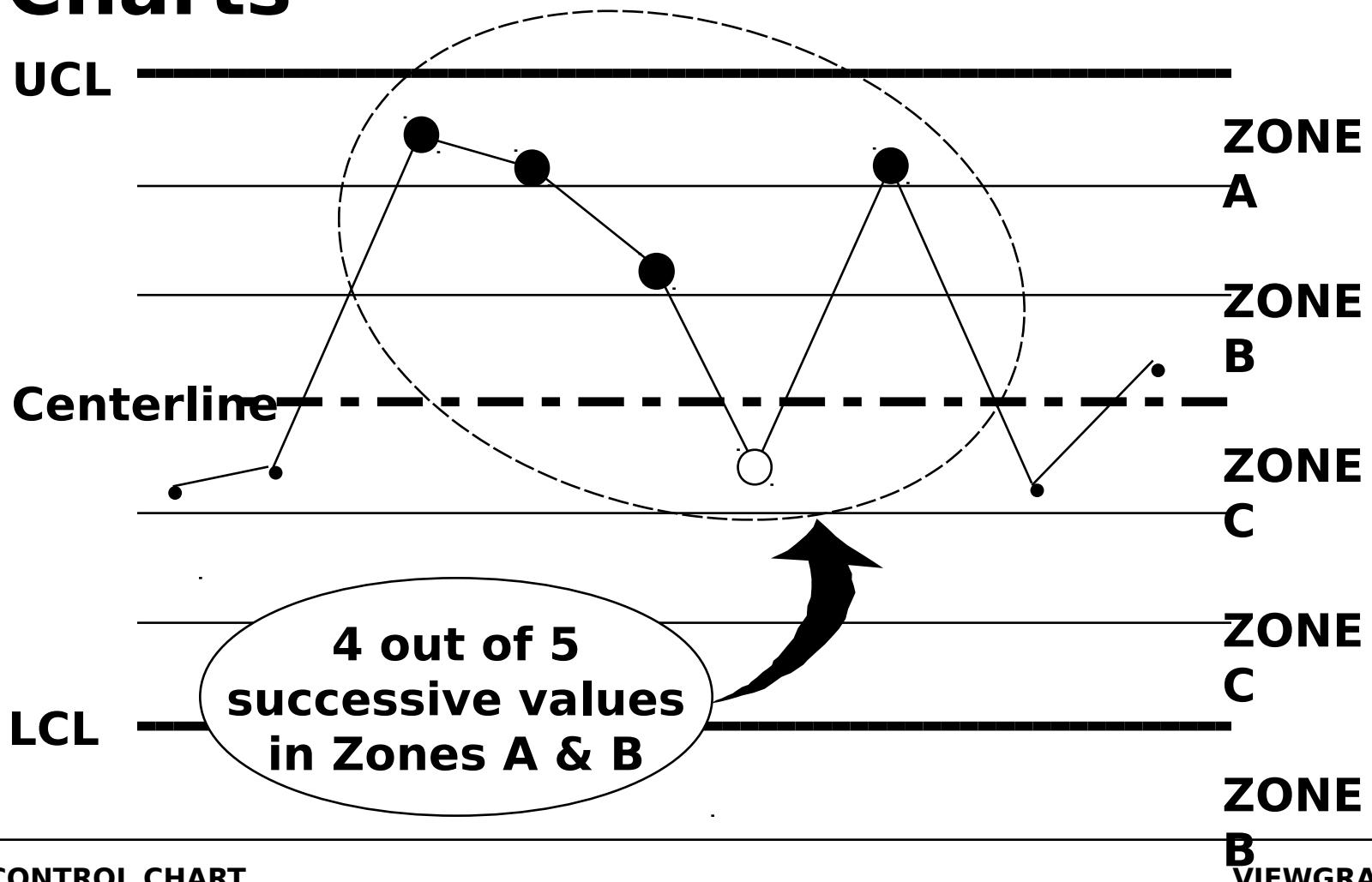
ZONE  
C

ZONE  
C

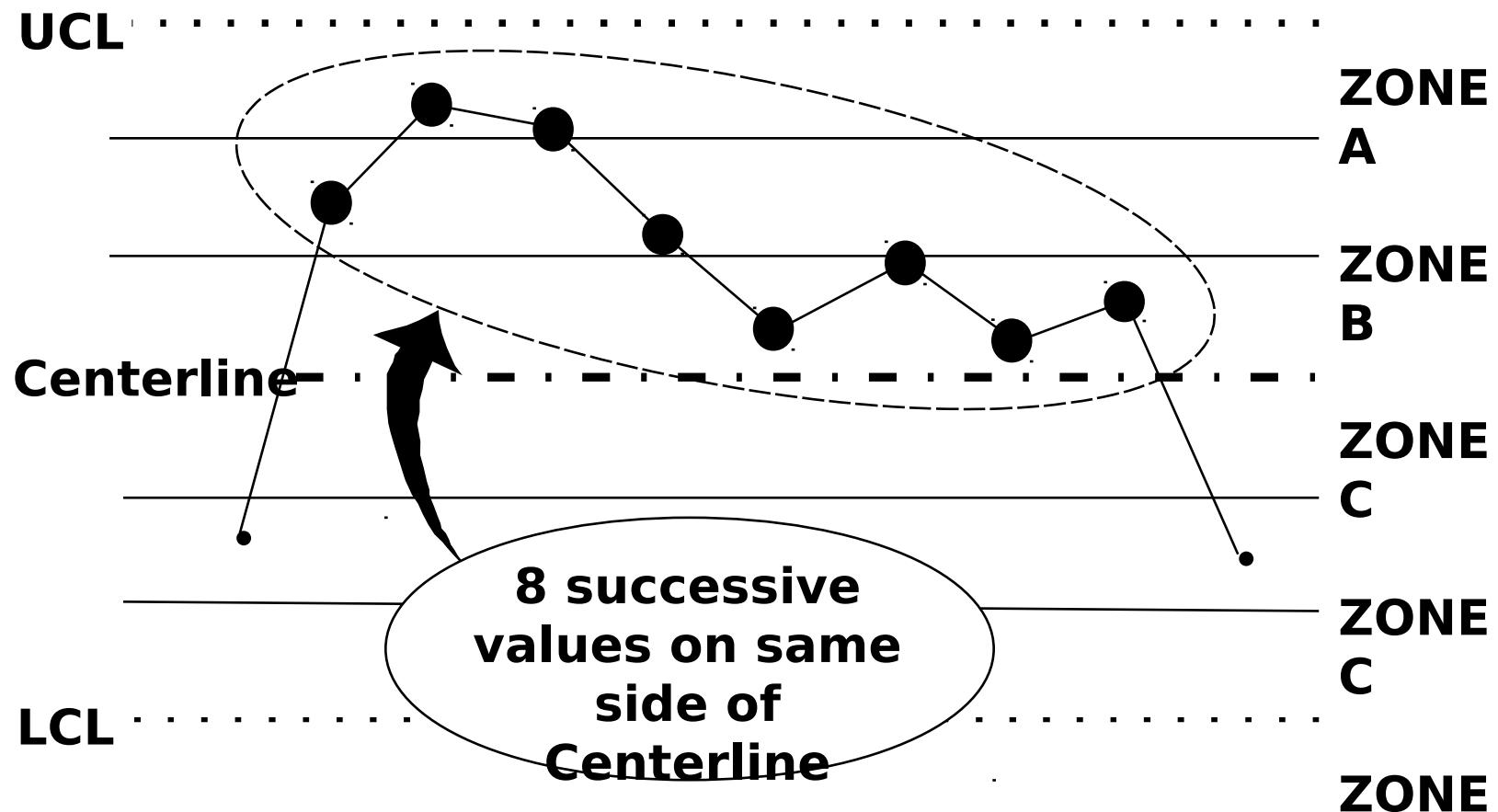
ZONE  
B

2 out of 3  
successive values  
in Zone A

# Rule 3 - Interpreting X-Bar & R Charts



# Rule 4 - Interpreting X-Bar & R Charts



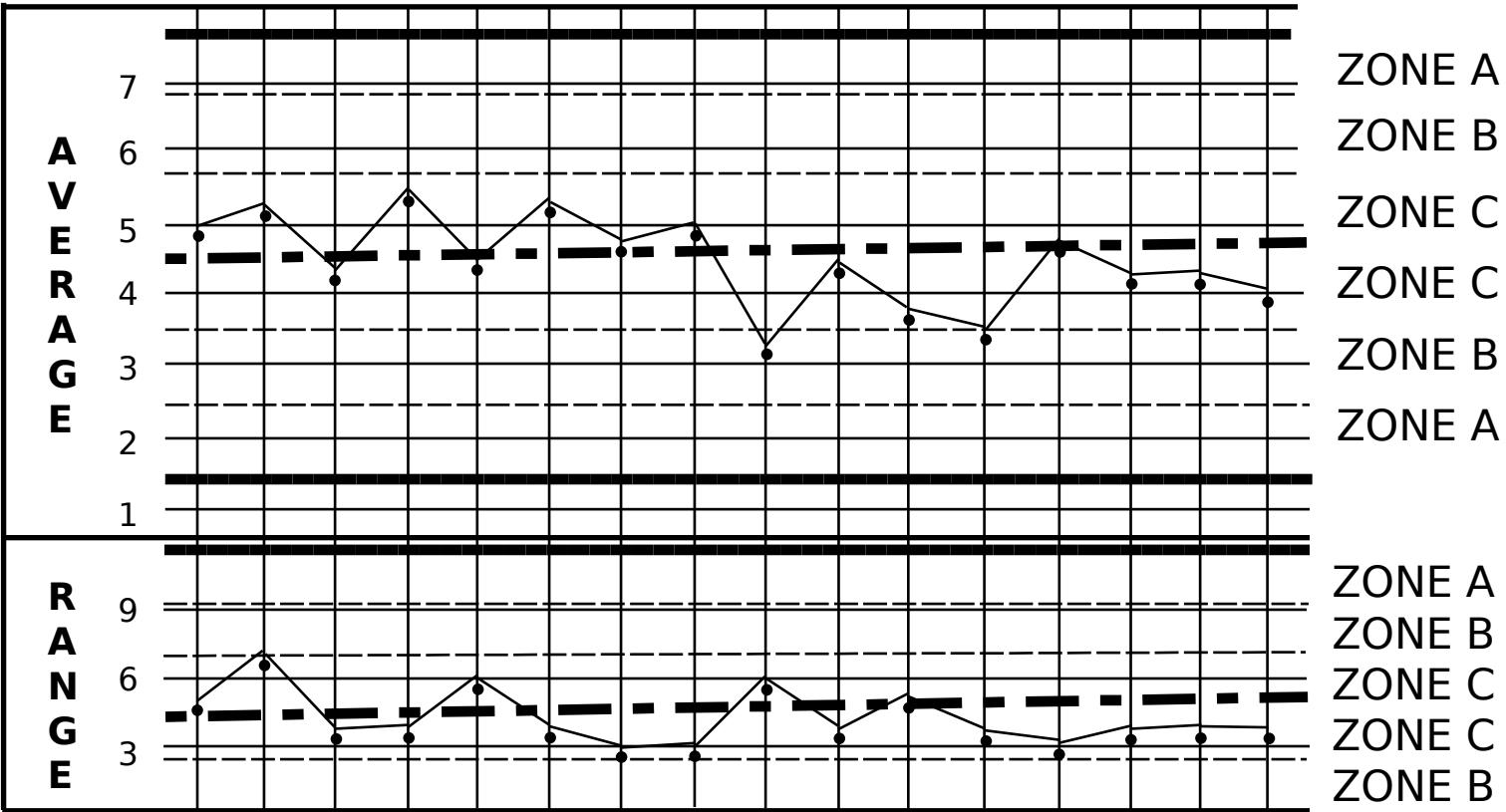
# ***EXERCISE 1***

## ***Values of X-Bar and Ranges***

	1	2	3	4	5	6	7	8	9	1	1	1	1	1	16
X <sub>1</sub>	6	2	5	3	2	5	4	7	2	5	1	2	3	4	5
X <sub>2</sub>	5	7	6	6	8	4	6	4	3	5	1	4	3	4	4
X <sub>3</sub>	2	9	4	6	3	8	3	4	7	2	6	2	6	6	7
X <sub>4</sub>	7	3	2	7	5	4	6	5	1	6	5	2	6	2	4
X-Bar	5.0	5.3	4.3	5.	4.	5.	4.	5.	3.	4.	3.	3.5	4.8	4.3	4.34.0
R	5	7	4	4	6	4	3	3	6	4	5	4	3	4	4

# ***EXERCISE 1***

## ***X-Bar & R Control Chart***



Note: Solid lines represent the grid used in this module; dashed lines separate zones.

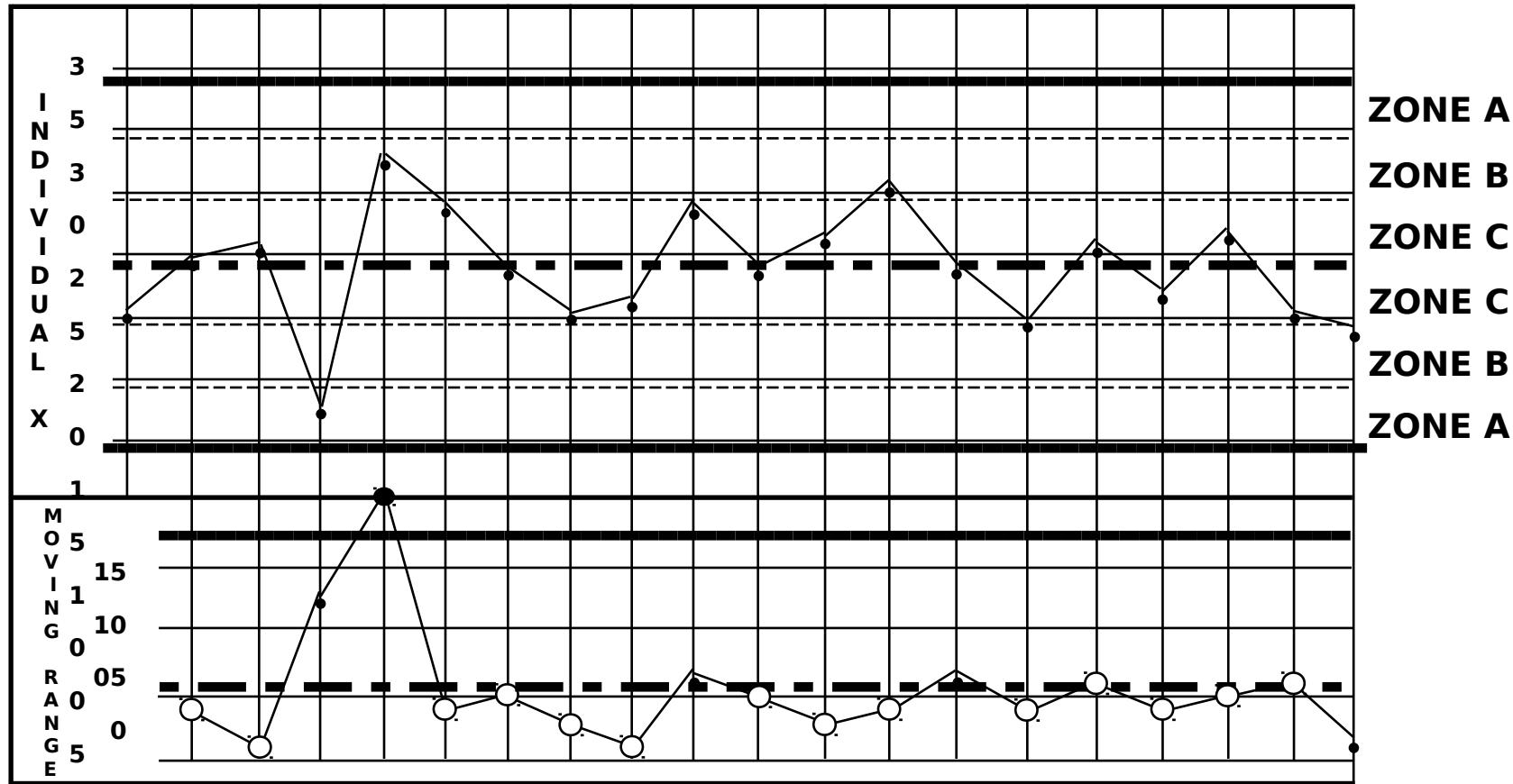
## ***EXERCISE 2***

### ***Values of Moving Ranges***

Date	1	2	3	4	5	6	7	8	9	1	11	12	13	14	15	16	17	18	19	2		
X Values	1	2	21	8	28	24	19	16	1	24	19	22	26	19	15	21	17	22	16	14		
mR	6	0	4	1	13	20	4	5	3	7	1	7	5	3	4	7	4	6	4	5	6	2

# ***EXERCISE 2***

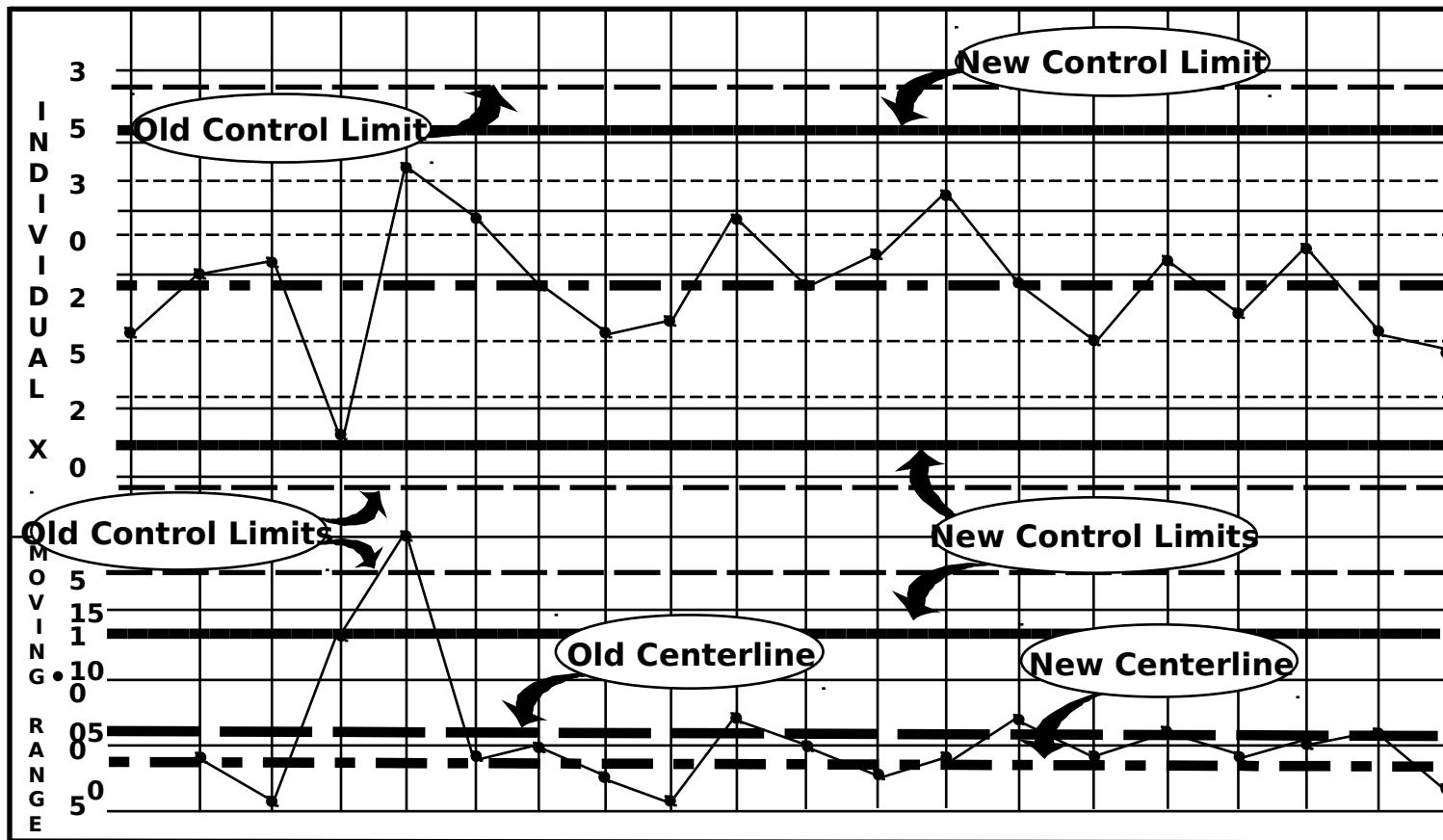
## ***XmR Control Chart***



Note: Solid lines represent the grid used in this module; dashed lines separate the zones in the upper plot.

# **EXERCISE 2**

## **XmR Control Chart Revised for Inflated Limits**



Note: Solid lines represent the grid used in this module; light dashed lines divide the zones in the upper plot.